

We claim:

1. A method of determining an optimum bit load per subchannel in a multicarrier  
2 system with forward error correction, comprising:

3 computing one or more values of a maximum number of symbol errors that  
4 can be corrected  $t$ , and a number of symbols in the information field  $K$  to determine  
5 the optimum bit load per subchannel in accordance with the following relationship:

6

$$1 - \left( 1 - W(s, z, K) \mathcal{E}_s^{\frac{1}{0.5 \cdot sz + 1}} \right)^{1/\alpha} \\ = \omega(b(\gamma_{\text{eff}}, s, z)) \left( 1 - 2^{-b(\gamma_{\text{eff}}, s, z)/2} \right) \text{erfc} \left( \sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} / (2^{b(\gamma_{\text{eff}}, s, z)+1} - 2)} \right), \text{ and} \\ \times \left[ 2 - \left( 1 - 2^{-b(\gamma_{\text{eff}}, s, z)/2} \right) \text{erfc} \left( \sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} / (2^{b(\gamma_{\text{eff}}, s, z)+1} - 2)} \right) \right]$$

8

$$W(s, z, K) = \left[ \frac{\Gamma(K + s + sz)}{\Gamma(K + s + 0.5 \cdot sz) \Gamma(0.5 \cdot sz + 1)} \right]^{-1/(0.5 \cdot sz + 1)}$$

10

$$11 \quad \text{wherein } \omega(b) = \frac{4}{2b + 3},$$

12

$$13 \quad \Gamma(x) = (x-1)!,$$

14

15  $s$  represents a number of discrete-multi-tone symbols in a frame,  $z$  represents a  
16 number of control code symbols per discrete-multi-tone symbol,  $b$  represents a  
17 number of bit positions of a quadrature-amplitude-modulation symbol,  $\omega(b)$   
18 represents an average fraction of erroneous bits in an erroneous  $b$ -sized  
19 quadrature-amplitude-modulation symbol,  $\gamma_{\text{eff}}$  represents an effective signal-to-noise  
20 ratio; and

21                   selecting the maximum number of symbol errors that can be corrected  $t$ , and  
22                   the number of symbols in the information field  $K$  such that the uncoded bit error rate  
23                    $p_b$  that produces a symbol error rate that is less than or equal to the target symbol  
24                   error rate is increased.

1           2.       The method of claim 1 wherein the effective signal-to-noise ratio  $\gamma_{\text{eff}}$  is an  
2           average signal-to-noise ratio of at least a subset of the channels.

1           3.       The method of claim 1 wherein the size of the frame ranges from 0 to  
2            $N_{\max,s,zs}$  symbols.

1           4.       The method of claim 1 further comprising:  
2                   determining a difference  $\Theta$  between a bit error rate prior to decoding and the  
3                   target bit error rate ( $p_e$ ) in accordance with the following relationship:

4

$$5 \quad \Theta(K) = \omega(b(\gamma_{\text{eff}}, s, z))p_{QAM} - p_e, \text{ and}$$

6

$$7 \quad \omega(b(\gamma_{\text{eff}}, s, z))p_{QAM} = \omega\left(\frac{\alpha}{sn_{\text{eff}}}(K + s + zs)\right) \left(1 - 2^{-\frac{\alpha}{2sn_{\text{eff}}}(K + s + zs)}\right) \operatorname{erfc}\left(\sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} \left(2^{\frac{\alpha}{sn_{\text{eff}}}(K + s + zs) + 1} - 2\right)}\right) \\ \times \left[2 - \left(1 - 2^{-\frac{\alpha}{2sn_{\text{eff}}}(K + s + zs)}\right) \operatorname{erfc}\left(\sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} \left(2^{\frac{\alpha}{sn_{\text{eff}}}(K + s + zs) + 1} - 2\right)}\right)\right]$$

8

9                   wherein  $p_{QAM}$  represents a probability of error in transmitting a  
10                  quadrature-amplitude-modulation waveform representing a  $2^b$  point constellation, and  
11                   $p_e$  represents a channel symbol error rate; and

12        comparing the value of  $\Theta(0)$  and  $\Theta(N_{max}-s-zs)$  to 0; and  
13        setting the value of K to a predetermined value in response to the comparing.

1        5.        The method of claim 4 wherein when  $\Theta(0)<0$  and  $\Theta(N_{max}-s-sz)<0$  , setting  
2         $K=N_{max}-s-zs$ .

1        6.        The method of claim 1 further comprising setting  $b(\gamma_{eff}, s, z)$  equal to

2

$$\frac{\alpha \ N_{max}}{s \ n_{eff}} .$$

1        7.        The method of claim 1 wherein when  $\Theta(0)>0$  and  $\Theta(N_{max}-s-sz)>0$  , setting  
2         $K=N_{max}-1$ .

1        8.        The method of claim 7 further comprising setting  $b(\gamma_{eff}, s, z)$  equal to  
2         $b(\gamma_{eff}, 1, 0)$ .

1        9.        A method of selecting forward error correction parameters in a channel having  
2        a plurality of subchannels in a multicarrier communications system, comprising:

3                determining a signal-to-noise ratio representing a subset of the subchannels to  
4                provide said representative performance measurement;

5                storing, in a table, the number (s) of discrete multi-tone symbols in a  
6                forward-error-correction frame, the number (z) of forward-error-correction control  
7                symbols in the discrete multitone symbol associated with the signal-to-noise ratio,  
8                and the number of subchannels associated with the signal-to-noise ratio, and a net  
9                coding gain for different values of s, z, signal-to-noise ratios and numbers of  
10                subchannels; and

11                   selecting forward error correction parameters of the channel based on the net  
12                   coding gain by applying an approximation to a subset of values in the table.

1           10.       The method of claim 9 wherein the approximation is a bilinear approximation.

1           11.       A method of selecting forward error correction parameters in a channel having  
2                   a plurality of subchannels in a multicarrier communications system, comprising:

3                   determining a signal-to-noise ratio representing a subset of the subchannels to  
4                   provide said representative performance measurement;

5                   storing, in a table, the number (s) of discrete multi-tone symbols in a  
6                   forward-error-correction frame, the number (z) of forward-error-correction control  
7                   symbols in the discrete multitone symbol associated with the signal-to-noise ratio, the  
8                   maximum number of transmissions (k) and the number of subchannels associated  
9                   with the signal-to-noise ratio, and a net coding gain for different values of s, z,  
10                  signal-to-noise ratios and numbers of subchannels; and

11                  selecting forward error correction parameters of the channel based on the net  
12                  coding gain by applying an approximation to a subset of values in the table.

1           12.       The method of claim 11 wherein the approximation is a bilinear  
2                  approximation.

1           13.       The method of claim 11 wherein and the values of s and z are in accordance  
2                  with the G.dmt standard.

1           14.       The method of claim 13 wherein the values of s and z are in accordance with  
2                  the G.lite standard, such that a subset of the tables associated with the values of s and  
3                  z in accordance with the G.dmt standard are used when the channel uses the G.lite  
4                  standard.

1 15. A method of increasing a bit load of a multicarrier system comprising a  
2 channel having a plurality of subchannels, comprising:

3 determining a bit load for at least one subchannel based on a target symbol error  
4 rate  $\varepsilon_s$ , a maximum number of symbol errors that can be corrected  $t$ , a number of symbols  
5 in an information field  $K$ , and a maximum number of transmissions  $k$ , and a number of  
6 bits per subchannel; and

7 selecting the maximum number of symbol errors  $t$ , the number of symbols in the  
8 information field  $K$  and the maximum number of transmissions  $k$ , such that a net coding  
9 gain is increased, and wherein  $t$ ,  $K$  and  $k$  are also selected such that no forward error  
10 correction is applied when the number of subchannels exceeds a predetermined threshold  
11 number of subchannels.

1 16. The method of claim 15 wherein the channel uses the G.dmt standard.

1 17. The method of claim 15 wherein the channel uses the G.lite standard.

1 18. A method of determining an optimum bit load per subchannel in a multicarrier  
2 system with forward error correction, comprising:

3 computing one or more values of a maximum number of symbol errors that  
4 can be corrected  $t$ , and a number of symbols in the information field  $K$  to determine  
5 the optimum bit load per subchannel in accordance with the following relationship:

6

$$1 - \left( 1 - W(s, z, K) \varepsilon_s^{\frac{1}{0.5 \cdot sz + 1}} \right)^{1/\alpha}$$

7

$$= \omega(b(\gamma_{\text{eff}}, s, z)) \left( 1 - 2^{-b(\gamma_{\text{eff}}, s, z)/2} \right) \operatorname{erfc} \left( \sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} / (2^{b(\gamma_{\text{eff}}, s, z)+1} - 2)} \right), \text{ and}$$
$$\times \left[ 2 - \left( 1 - 2^{-b(\gamma_{\text{eff}}, s, z)/2} \right) \operatorname{erfc} \left( \sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} / (2^{b(\gamma_{\text{eff}}, s, z)+1} - 2)} \right) \right]$$

9 
$$W(s, z, K) = \left[ \frac{\Gamma(K + \rho s + sz)}{\Gamma(K + \rho s + 0.5 \cdot sz) \Gamma(0.5 \cdot sz + 1)} \right]^{-1/(0.5 \cdot sz + 1)}$$

10

11 
$$\text{wherein } \omega(b) = \frac{4}{2b + 3},$$

12

13 
$$\Gamma(x) = (x-1)!,$$

14

15 s represents a number of discrete-multi-tone symbols in a frame, z represents a  
16 number of control code symbols per discrete-multi-tone symbol, b represents a  
17 number of bit positions of a quadrature-amplitude-modulation symbol,  $\omega(b)$   
18 represents an average fraction of erroneous bits in an erroneous b-sized  
19 quadrature-amplitude-modulation symbol,  $\gamma_{\text{eff}}$  represents an effective signal-to-noise  
20 ratio, and  $\rho$  represents a number of overhead symbols per discrete multi-tone symbol;  
21 and

22 selecting the maximum number of symbol errors that can be corrected  $t$ , and  
23 the number of symbols in the information field  $K$  such that the uncoded bit error rate  
24  $p_b$  that produces a symbol error rate that is less than or equal to the target symbol  
25 error rate is increased.

1 19. The method of claim 18 wherein the effective signal-to-noise ratio  $\gamma_{\text{eff}}$  is an  
2 average signal-to-noise ratio of at least a subset of the channels.

1 20. The method of claim 18 wherein the size of the frame ranges from 0 to  
2  $N_{\text{max}} \cdot \rho s \cdot sz$  symbols.

1        21.    The method of claim 18 further comprising:  
 2                determining a difference  $\Theta$  between a bit error rate prior to decoding and the  
 3                target bit error rate ( $p_e$ ) in accordance with the following relationship:

4

$$5 \quad \Theta(K) = \omega(b(\gamma_{\text{eff}}, s, z))p_{QAM} - p_e, \text{ and}$$

6

$$7 \quad \omega(b(\gamma_{\text{eff}}, s, z))p_{QAM} \\ = \omega\left(\frac{\alpha}{sn_{\text{eff}}}(K + \rho s + z s)\right) \left(1 - 2^{-\frac{\alpha}{2sn_{\text{eff}}}(K + \rho s + z s)}\right) \operatorname{erfc}\left(\sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10}} \left(2^{\frac{\alpha}{sn_{\text{eff}}}(K + \rho s + z s) + 1} - 2\right)\right) \\ \times \left[2 - \left(1 - 2^{-\frac{\alpha}{2sn_{\text{eff}}}(K + \rho s + z s)}\right) \operatorname{erfc}\left(\sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10}} \left(2^{\frac{\alpha}{sn_{\text{eff}}}(K + \rho s + z s) + 1} - 2\right)\right)\right]$$

8

9        wherein  $p_{QAM}$  represents a probability of error in transmitting a  
 10      quadrature-amplitude-modulation waveform representing a  $2^b$  point constellation, and  
 11       $p_e$  represents a channel symbol error rate; and  
 12      comparing the value of  $\Theta(0)$  and  $\Theta(N_{\text{max}} - \rho s - z s)$  to 0; and  
 13      setting the value of K to a predetermined value in response to the comparing.

1        22.    The method of claim 18 wherein when  $\Theta(0) < 0$  and  $\Theta(N_{\text{max}} - \rho s - z s) < 0$ , setting  
 2       $K = N_{\text{max}} - \rho s - z s$ .

1        23.    The method of claim 22 further comprising setting  $b(\gamma_{\text{eff}}, s, z)$  equal to

2

3

$$\frac{\alpha N_{\text{max}}}{s n_{\text{eff}}} .$$

1        24.     The method of claim 18 wherein when  $\Theta(0)>0$  and  $\Theta(N_{max}\rho s - sz)>0$  , setting  
2         $K=N_{max}\rho$ .

1        25.     The method of claim 24 further comprising setting  $b(\gamma_{eff}, s, z)$  equal to  
2         $b(\gamma_{eff}, 1, 0)$ .

1        26.     An apparatus for determining an optimum bit load per subchannel in a  
2        multicarrier system with forward error correction, comprising:

3                means for computing one or more values of a maximum number of symbol  
4        errors that can be corrected  $t$ , and a number of symbols in the information field  $K$  to  
5        determine the optimum bit load per subchannel in accordance with the following  
6        relationship:

7

$$1 - \left( 1 - W(s, z, K) \epsilon_s^{\frac{1}{0.5 \cdot sz + 1}} \right)^{1/\alpha}$$

8         $= \omega(b(\gamma_{eff}, s, z)) \left( 1 - 2^{-b(\gamma_{eff}, s, z)/2} \right) \operatorname{erfc} \left( \sqrt{3 \cdot 10^{\gamma_{eff}/10}} / \left( 2^{b(\gamma_{eff}, s, z)+1} - 2 \right) \right), \text{ and}$ 
$$\times \left[ 2 - \left( 1 - 2^{-b(\gamma_{eff}, s, z)/2} \right) \operatorname{erfc} \left( \sqrt{3 \cdot 10^{\gamma_{eff}/10}} / \left( 2^{b(\gamma_{eff}, s, z)+1} - 2 \right) \right) \right]$$

9

$$10        W(s, z, K) = \left[ \frac{\Gamma(K + s + sz)}{\Gamma(K + s + 0.5 \cdot sz) \Gamma(0.5 \cdot sz + 1)} \right]^{-1/(0.5 \cdot sz + 1)}$$

11

12        wherein  $\omega(b) = \frac{4}{2b + 3}$ ,

13

14         $I(x) = (x-1)!,$

15

16 s represents a number of discrete-multi-tone symbols in a frame, z represents a  
17 number of control code symbols per discrete-multi-tone symbol, b represents a  
18 number of bit positions of a quadrature-amplitude-modulation symbol,  $\omega(b)$   
19 represents an average fraction of erroneous bits in an erroneous b-sized  
20 quadrature-amplitude-modulation symbol,  $\gamma_{eff}$  represents an effective signal-to-noise  
21 ratio; and

22 means for selecting the maximum number of symbol errors that can be  
23 corrected t, and the number of symbols in the information field K such that the  
24 uncoded bit error rate  $p_b$  that produces a symbol error rate that is less than or equal to  
25 the target symbol error rate is increased.

1 27. The apparatus of claim 26 wherein the effective signal-to-noise ratio  $\gamma_{eff}$  is an  
2 average signal-to-noise ratio of at least a subset of the channels.

1 28. The apparatus of claim 22 wherein the size of the frame ranges from 0 to  
2  $N_{max-s-zs}$  symbols.

1 29. The apparatus of claim 26 further comprising:

2 means for determining a difference  $\Theta$  between a bit error rate prior to  
3 decoding and the target bit error rate ( $p_e$ ) in accordance with the following  
4 relationship:

5

6 
$$\Theta(K) = \omega(b(\gamma_{eff}, s, z))p_{QAM} - p_e, \text{ and}$$

7

$$\begin{aligned}
 8 \quad & \omega(b(\gamma_{\text{eff}}, s, z)) p_{QAM} \\
 & = \omega\left(\frac{\alpha}{sn_{\text{eff}}}(K+s+zs)\right) \left(1 - 2^{-\frac{\alpha}{2sn_{\text{eff}}}(K+s+zs)}\right) \operatorname{erfc}\left(\sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} \left(2^{\frac{\alpha}{sn_{\text{eff}}}(K+s+zs)+1} - 2\right)}\right) \\
 & \quad \times \left[2 - \left(1 - 2^{-\frac{\alpha}{2sn_{\text{eff}}}(K+s+zs)}\right) \operatorname{erfc}\left(\sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} \left(2^{\frac{\alpha}{sn_{\text{eff}}}(K+s+zs)+1} - 2\right)}\right)\right]
 \end{aligned}$$

9  
 10      wherein  $p_{QAM}$  represents a probability of error in transmitting a  
 11      quadrature-amplitude-modulation waveform representing a  $2^b$  point constellation, and  
 12       $p_e$  represents a channel symbol error rate; and

13      means for comparing the value of  $\Theta(0)$  and  $\Theta(N_{\max}-s-zs)$  to 0; and  
 14      means for setting the value of K to a predetermined value in response to the  
 15      comparing.

1      30.      The apparatus of claim 26 wherein when  $\Theta(0) < 0$  and  $\Theta(N_{\max}-s-zs) < 0$  , setting  
 2       $K=N_{\max}-s-zs$ .

1      31.      The apparatus of claim 30 further comprising setting  $b(\gamma_{\text{eff}}, s, z)$  equal to  
 2  
 3       $\frac{\alpha N_{\max}}{s n_{\text{eff}}}.$

1      32.      The apparatus of claim 30 wherein when  $\Theta(0) > 0$  and  $\Theta(N_{\max}-s-zs) > 0$  , setting  
 2       $K=N_{\max}-1$ .

1      33.      The apparatus of claim 32 further comprising setting  $b(\gamma_{\text{eff}}, s, z)$  equal to  
 2       $b(\gamma_{\text{eff}}, 1, 0)$ .

1       34. An apparatus for selecting forward error correction parameters in a channel  
2       having a plurality of subchannels in a multicarrier communications system,  
3       comprising:

4               means for determining a signal-to-noise ratio representing a subset of the  
5       subchannels to provide said representative performance measurement;

6               means for storing, in a table, the number (s) of discrete multi-tone symbols in  
7       a forward-error-correction frame, the number (z) of forward-error-correction control  
8       symbols in the discrete multitone symbol associated with the signal-to-noise ratio,  
9       and the number of subchannels associated with the signal-to-noise ratio, and a net  
10      coding gain for different values of s, z, signal-to-noise ratios and numbers of  
11      subchannels; and

12               means for selecting forward error correction parameters of the channel based  
13      on the net coding gain by applying an approximation to a subset of values in the table.

1       35. The apparatus of claim 34 wherein the approximation is a bilinear  
2       approximation.

1       36. An apparatus for selecting forward error correction parameters in a channel  
2       having a plurality of subchannels in a multicarrier communications system,  
3       comprising:

4               means for determining a signal-to-noise ratio representing a subset of the  
5       subchannels to provide said representative performance measurement;

6               means for storing, in a table, the number (s) of discrete multi-tone symbols in  
7       a forward-error-correction frame, the number (z) of forward-error-correction control  
8       symbols in the discrete multitone symbol associated with the signal-to-noise ratio, the  
9       maximum number of transmissions (k) and the number of subchannels associated  
10      with the signal-to-noise ratio, and a net coding gain for different values of s, z,  
11      signal-to-noise ratios and numbers of subchannels; and

12                   means for selecting forward error correction parameters of the channel based  
13                   on the net coding gain by applying an approximation to a subset of values in the table.

1           37.    The apparatus of claim 36 wherein the approximation is a bilinear  
2           approximation.

1           38.    The apparatus of claim 36 wherein the values of s and z are in accordance  
2           with the G.dmt standard.

1           39.    The apparatus of claim 38 wherein the values of s and z are in accordance  
2           with the G.lite standard, such that a subset of the tables associated with the values of s  
3           and z in accordance with the G.dmt standard are used when the channel uses the  
4           G.lite standard.

1           40.    An apparatus for increasing a bit load of a multicarrier system comprising a  
2           channel having a plurality of subchannels, comprising:

3                   means for determining a bit load for at least one subchannel based on a target  
4           symbol error rate  $\epsilon_s$ , a maximum number of symbol errors that can be corrected t, a  
5           number of symbols in an information field K, and a maximum number of transmissions k,  
6           and a number of bits per subchannel; and

7                   means for selecting the maximum number of symbol errors t, the number of  
8           symbols in the information field K and the maximum number of transmissions k, such  
9           that a net coding gain is increased wherein the means for also selects t, K and k such that  
10           no forward error correction is applied when the number of subchannels exceeds a  
11           predetermined threshold number of subchannels.

1 41. An apparatus for determining an optimum bit load per subchannel in a  
 2 multicarrier system with forward error correction, comprising:

3 means for computing one or more values of a maximum number of symbol  
 4 errors that can be corrected  $t$ , and a number of symbols in the information field  $K$  to  
 5 determine the optimum bit load per subchannel in accordance with the following  
 6 relationship:

7

$$1 - \left( 1 - W(s, z, K) \epsilon_s^{\frac{1}{0.5 \cdot sz + 1}} \right)^{1/\alpha} \\ = \omega(b(\gamma_{\text{eff}}, s, z)) \left( 1 - 2^{-b(\gamma_{\text{eff}}, s, z)/2} \right) \operatorname{erfc} \left( \sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} / (2^{b(\gamma_{\text{eff}}, s, z)+1} - 2)} \right), \text{ and} \\ \times \left[ 2 - \left( 1 - 2^{-b(\gamma_{\text{eff}}, s, z)/2} \right) \operatorname{erfc} \left( \sqrt{3 \cdot 10^{\gamma_{\text{eff}}/10} / (2^{b(\gamma_{\text{eff}}, s, z)+1} - 2)} \right) \right]$$

9

$$10 W(s, z, K) = \left[ \frac{\Gamma(K + \rho s + sz)}{\Gamma(K + \rho s + 0.5 \cdot sz) \Gamma(0.5 \cdot sz + 1)} \right]^{-1/(0.5 \cdot sz + 1)}$$

11

$$12 \text{ wherein } \omega(b) = \frac{4}{2b + 3},$$

13

$$14 I(x) = (x-1)!,$$

15

16  $s$  represents a number of discrete-multi-tone symbols in a frame,  $z$  represents a  
 17 number of control code symbols per discrete-multi-tone symbol,  $b$  represents a  
 18 number of bit positions of a quadrature-amplitude-modulation symbol,  $\omega(b)$   
 19 represents an average fraction of erroneous bits in an erroneous  $b$ -sized  
 20 quadrature-amplitude-modulation symbol,  $\gamma_{\text{eff}}$  represents an effective signal-to-noise  
 21 ratio, and  $\rho$  represents a number of overhead symbols per discrete multi-tone symbol;  
 22 and

23 means for selecting the maximum number of symbol errors that can be  
 24 corrected  $t$ , and the number of symbols in the information field  $K$  such that the  
 25 uncoded bit error rate  $p_b$  that produces a symbol error rate that is less than or equal to  
 26 the target symbol error rate is increased.

1 42. The apparatus of claim 41 wherein the effective signal-to-noise ratio  $\gamma_{eff}$  is an  
 2 average signal-to-noise ratio of at least a subset of the channels.

1 43. The apparatus of claim 41 wherein the size of the frame ranges from 0 to  
 2  $N_{max}\rho s\text{-}sz$  symbols.

1 44. The apparatus of claim 41 further comprising:  
 2 means for determining a difference  $\Theta$  between a bit error rate prior to  
 3 decoding and the target bit error rate ( $p_e$ ) in accordance with the following  
 4 relationship:

5

$$6 \quad \Theta(K) = \omega(b(\gamma_{eff}, s, z))p_{QAM} - p_e,$$

7

$$8 \quad \omega(b(\gamma_{eff}, s, z))p_{QAM} = \omega\left(\frac{\alpha}{sn_{eff}}(K + \rho s + z s)\right) \left(1 - 2^{-\frac{\alpha}{2sn_{eff}}(K + \rho s + z s)}\right) erfc\left(\sqrt{3 \cdot 10^{\gamma_{eff}/10} \left(2^{\frac{\alpha}{sn_{eff}}(K + \rho s + z s) + 1} - 2\right)}\right) \\ \times \left[2 - \left(1 - 2^{-\frac{\alpha}{2sn_{eff}}(K + \rho s + z s)}\right) erfc\left(\sqrt{3 \cdot 10^{\gamma_{eff}/10} \left(2^{\frac{\alpha}{sn_{eff}}(K + \rho s + z s) + 1} - 2\right)}\right)\right]$$

9  
 10 wherein  $p_{QAM}$  represents a probability of error in transmitting a  
 11 quadrature-amplitude-modulation waveform representing a  $2^b$  point constellation, and  
 12  $p_e$  represents a channel symbol error rate;

13 comparing the value of  $\Theta(0)$  and  $\Theta(N_{max}-\rho s-zs)$  to 0; and  
14 setting the value of K to a predetermined value in response to the comparing.

1 45. The apparatus of claim 41 wherein when  $\Theta(0)<0$  and  $\Theta(N_{max}-\rho s-sz)<0$  ,  
2 setting  $K=N_{max}-\rho s-zs$ .

1 46. The apparatus of claim 45 further comprising setting  $b(\gamma_{eff}, s, z)$ equal to  
2

3 
$$\frac{\alpha}{s} \frac{N_{max}}{n_{eff}} .$$

1 47. The apparatus of claim 41 wherein when  $\Theta(0)>0$  and  $\Theta(N_{max}-\rho s-sz)>0$  ,  
2 setting  $K=N_{max}-\rho$ .

1 48. The apparatus of claim 47 further comprising setting  $b(\gamma_{eff}, s, z)$ equal to  
2  $b(\gamma_{eff}, 1, 0)$ .